

# United States Air Force Research Laboratory



## SCHEDULING AIRCREWS 3: DEPLOYMENT

James C. Miller

HUMAN EFFECTIVENESS DIRECTORATE  
BIOSCIENCES AND PROTECTION DIVISION  
FATIGUE COUNTERMEASURES BRANCH  
8248 CHENNAULT PATH  
BROOKS CITY-BASE TX 78235-5105

May 2005

*Approved for public release, distribution unlimited.*

## NOTICES

This report is published in the interest of scientific and technical information exchange and does not constitute approval or disapproval of its ideas or findings.

This report is published as received and has not been edited by the publication staff of the Air Force Research Laboratory.

Using Government drawings, specifications, or other data included in this document for any purpose other than Government-related procurement does not in any way obligate the US Government. The fact that the Government formulated or supplied the drawings, specifications, or other data, does not license the holder or any other person or corporation, or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

The Office of Public Affairs has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

//SIGNED//

JAMES C. MILLER, Ph.D.  
Project Scientist

//SIGNED//

F. WESLEY BAUMGARDNER, Ph.D.  
Deputy, Biosciences and Protection Division

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of Information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of Information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. <b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b>				
1. REPORT DATE (DD-MM-YYYY) May 2005		2. REPORT TYPE Interim		3. DATES COVERED (From - To) 1 Jun -30 Sep 2004
4. TITLE AND SUBTITLE  SCHEDULING AIRCREWS 3: DEPLOYMENT			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) James C. Miller			5d. PROJECT NUMBER 7757	
			5e. TASK NUMBER P9	
			5f. WORK UNIT NUMBER 04	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Human Effectiveness Directorate Biosciences and Protection Division Fatigue Countermeasures Branch Brooks City-Base, TX 78235			8. PERFORMING ORGANIZATION REPORT	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Human Effectiveness Directorate Biosciences and Protection Division Fatigue Countermeasures Branch  8248 Chennault Path Brooks City-Base, TX 78235			10. SPONSOR/MONITOR'S ACRONYM(S)  AFRL/HE	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-HE-BR-TR-2005-0047	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT The objective of this Memorandum was to develop aircrew work-rest guidance that dealt with the jet lag issues associated with deployments across time zones. It was hoped that this guidance could be used by operational commanders to determine when best to deploy their crews. The calculations in this Memorandum were based upon the U.S. Department of Defense Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) applied model. The SAFTE applied model integrated the effects of length of prior wakefulness, amount of sleep and circadian rhythm. This applied model was implemented in the Windows program, Fatigue Avoidance Scheduling Tool (FAST™, NTI Inc., Dayton OH), which was used to make the calculations and to draw the figures shown in this Memorandum. Each of 12 scenarios was examined: 4.5-, 9- and 12.5-h changes to both the east and the west with subsequent day or night crew duty periods (CDPs). Recommendations were made for scheduling practices, including the use of alertness aids and sleep aids.				
15. SUBJECT TERMS Aircrew, schedules, fatigue, deployment, model-based, SAFTE, FAST				
16. SECURITY CLASSIFICATION OF:  UNCLASSIFIED			17. LIMITATION OF ABSTRACT  UNCLAS	18. NUMBER OF PAGES  21
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED	19a. NAME OF RESPONSIBLE PERSON Dr. James C. Miller	
			19b. TELEPHONE NUMBER (include area code) 210-536-2742	

## CONTENTS

	Page
PREFACE.....	v
SUMMARY.....	vi
INTRODUCTION.....	1
METHODS.....	2
EASTWARD DEPLOYMENT OF 4.5 HOURS.....	3
EASTWARD DEPLOYMENT OF 9 HOURS.....	5
EASTWARD DEPLOYMENT OF 12.5 HOURS.....	8
WESTWARD DEPLOYMENT OF 4.5 HOURS.....	10
WESTWARD DEPLOYMENT OF 9 HOURS.....	11
WESTWARD DEPLOYMENT OF 12.5 HOURS.....	13
USING BRIGHT LIGHT TO HELP ACCLIMATE.....	15
 <u>FIGURES</u>	
Figure 1. A rapid, eastward, 4.5-hour time zone change on Day 0, followed by day work and acclimation to the new time zone across 10 days. ....	4
Figure 2. A rapid, eastward, 4.5-hour time zone change on Day 0, followed by night work and acclimation to the new time zone across 2 weeks. ....	5
Figure 3. A rapid, eastward, 9-hour time zone change on Days 0 and 1, followed by day work and acclimation to the new time zone across 3 weeks. ....	6
Figure 4. A rapid, eastward, 9-hour time zone change on Days 0 and 1, followed by night work and acclimation to the new time zone across 3 weeks. ....	7
Figure 5. A rapid, eastward, 12.5-hour time zone change on Days 0 through 2, followed by day work and acclimation to the new time zone across 3 weeks. ....	8
Figure 6. A rapid, eastward, 12.5-hour time zone change on Days 0 through 2, followed by night work and acclimation to the new time zone across 3 weeks. ....	9
Figure 7. A rapid, westward, 4.5-hour, time zone change on Day 0, followed by day work and acclimation to the new time zone across 10 days. ....	10
Figure 8. A rapid, westward, 4.5-hour, time zone change on Day 0, followed by night work and acclimation to the new time zone across 3 weeks. ....	11
Figure 9. A rapid, westward, 9-hour, time zone change on Days 0 and 1, followed by day work and acclimation to the new time zone across 10 days. ....	12

Figure 10. A rapid, westward, 9-hour, time zone change on Days 0 and 1, followed by night work and acclimation to the new time zone across 10 days. ....	13
Figure 11. A rapid, westward, 12.5-hour, time zone change on Days 0 through 2, followed by day work and acclimation to the new time zone across 10 days. ....	14
Figure 12. A rapid, westward, 12.5-hour, time zone change on Days 0 through 2, followed by night work and acclimation to the new time zone across 3 weeks. ....	15

## PREFACE

This Technical Memorandum covers the project period of 1 to 30 September 2004. The work was performed under Job Order Number 7767P904. The project manager was Dr. James C. Miller, Senior Research Physiologist, Fatigue Countermeasures Branch, Biosciences and Protection Division, Air Force Research Laboratory (AFRL/HEPF).

This Technical Memorandum was written in response to aircrew fatigue problems identified for eastward deployment, identified to this Branch by A3 Transport Ops, 1 Canadian Air Division Headquarters, Winnipeg, MB Canada in September 2004.

This is one of several case-studies of operations produced by this Branch at the end of fiscal year 2004 using the U.S. Department of Defense Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) applied model<sup>1</sup>. SAFTE integrated the effects upon cognitive performance effectiveness of length of prior wakefulness, amount of sleep and circadian rhythm. In turn, the SAFTE applied model was implemented in the Windows® program, Fatigue Avoidance Scheduling Tool (*FAST*<sup>TM</sup>, NTI Inc., Dayton OH). For this case study, we used *FAST*<sup>TM</sup> beta version 1.0.13 with the following parameter values:

Model Parameters	Values
24-hr rhythm acrophase	18
12-hr rhythm phase offset	3
Relative amplitude of 12-hr rhythm	0.5
Sleep propensity mesor	0
Sleep propensity amplitude	0.55
Maximum sleep accumulation per minute	3.4
Performance rhythm amplitude (fixed %)	7
Performance rhythm amplitude (variable %)	5
Reservoir capacity	2880
Feedback amplitude	0.0031200
Sleep inertia time constant	0.04
Maximum inertia following awakening (%)	5
Performance use rate	0.5
Slow recovery	
K1	0.22
K2	0.5
K3	0.0015
Sleep environment	
Excellent	1
Moderate	0.83
Poor	0.5

---

<sup>1</sup> Hursh SR, Redmond DP, Johnson ML, Thorne DR, Belenky G, Balkin TJ, Storm WF, Miller JC, Eddy DR. (2004). Fatigue models for applied research in warfighting. *Aviation, Space and Environmental Medicine*, 75(3), Section II, Supplement, pp. A44-A53.

## SUMMARY

The objective of this Memorandum was to develop aircrew work-rest guidance that dealt with the jet lag issues associated with deployments across time zones. It was hoped that this guidance could be used by operational commanders to determine when best to deploy their crews. The calculations in this Memorandum were based upon the U.S. Department of Defense Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) applied model. The SAFTE applied model integrated the effects of length of prior wakefulness, amount of sleep and circadian rhythm. This applied model was implemented in the Windows program, Fatigue Avoidance Scheduling Tool (*FAST*<sup>TM</sup>, NTI Inc., Dayton OH), which was used to make the calculations and to draw the figures shown in this Memorandum. Each of 12 scenarios was examined: 4.5-, 9- and 12.5-h changes to both the east and the west with subsequent day or night crew duty periods (CDPs). Recommendations were made for scheduling practices, including the use of alertness aids and sleep aids.

## SCHEDULING AIRCREWS 3: DEPLOYMENT

### INTRODUCTION

The objective of the exercise documented here was to develop aircrew work-rest guidance that deals with the jet lag issues associated with deployments across time zones. It was hoped that this guidance could be used by operational commanders to determine when best to deploy their crews.

A rapid change<sup>2</sup> of time zones requires acclimation that is similar to a change to night work<sup>3</sup>. The main difference is the presence of the powerful daylight-darkness cue that usually helps the crew acclimate to the new time zone. Conversely, this cue usually impedes the night worker's ability to acclimate. Because the natural circadian<sup>4</sup> rhythm of the human is slightly longer than 24 hours, we acclimate slightly faster as we move west compared to moving east. Thus, the two directions are treated independently here. Each of 12 scenarios is examined: 4.5-, 9- and 12.5-h changes to both the east and the west with subsequent day or night crew duty periods (CDPs). Recommendations are made for scheduling practices, including the use of alertness aids and sleep aids. CAUTION: the ability to generalize these recommendations to situations that differ from the examples used here cannot be guaranteed. Contact this Fatigue Countermeasures Branch for advice concerning scenarios different from the examples used here.

The predictions in this Technical memorandum (TM) are based upon an assumption of good sleep hygiene for crews. Good sleep hygiene requires that management provide good sleeping quarters and that crews use the quarters and practice good pre-sleep behaviors. More specifically, it means that management must provide a quiet, cool, dark, comfortable sleeping space and protect and maintain it; and that each crewmember must sleep during the crew rest period, avoid sleep disturbing practices and not ingest sleep disturbing compounds (e.g., alcohol, caffeine, nicotine) before sleep.

Good sleep hygiene is much more easily attained for night sleep than for day sleep. There are many reasons for this. They include the difficulty of reversing the human circadian rhythm with respect to the day-night cycle and the low sleep propensity associated with daytime on the human body clock, the inherent tendency for humans to be socially active during the daytime hours and, usually, a lack of administrative and social support provided by management for crews' nocturnal waking periods.

No specific recommendations are made here for the use of melatonin during sleep periods or for the use of bright light during work. Melatonin is not currently approved for aircrew use in the United States Air Force<sup>5</sup>. Bright light can be helpful during night work to help

---

<sup>2</sup> Faster than 1 time zone per day.

<sup>3</sup> Miller JC. *Scheduling Aircrews 2: Nighttime Missions*. Technical Memorandum AFRL-HE-BR-TM-2005-00xx, Air Force Research Laboratory, Brooks City-Base TX, submitted Sep 2004.

<sup>4</sup> *Circa*, about; *dia*, one day.

<sup>5</sup> Air Force Surgeon General (22 Sep 2004). *Official Air Force Approved Aircrew Medications Quick Reference List*. AF/SGOP, Bolling AFB, DC.

suppress natural, nocturnal melatonin secretion and, concomitantly, reduce sleepiness. However, aircrews cannot normally use bright light at night in the cockpit, due to requirements to see and avoid other traffic in visual meteorological conditions.<sup>6</sup> The use of bright light for circadian rhythm adjustments in the new time zone is discussed at the end of this memo.

## METHODS

The calculations in this TM were based upon the U.S. Department of Defense Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) applied model. The SAFTE applied model integrated the effects of length of prior wakefulness, amount of sleep and circadian rhythm. This applied model was implemented in the Windows program, Fatigue Avoidance Scheduling Tool (*FAST*<sup>TM</sup>, NTI Inc., Dayton OH), which was used to make the calculations and to draw the figures shown in this Memorandum.

The *FAST*<sup>TM</sup> graphs in this TM depict a cognitive effectiveness prediction (left-hand vertical axis) as a function of time (horizontal axis). Work periods are shown as red bands on the horizontal axis and reflected up as wider red portions on the cognitive effectiveness prediction. Sleep periods are shown as blue bands across the horizontal axis.

The cognitive effectiveness prediction is for composite human performance on a number of cognitive tasks such as logical reasoning and mental arithmetic. The prediction (left-hand) axis is scaled up to 100%. The oscillating black and red line in the diagram represents expected group average performance (throughput) on cognitive tasks. We would expect the predicted performance of half of the people in a group to fall below this line.

The green area on the chart ends at the time for normal sleep, about 90% effectiveness. Our goal is to keep operation above this line during safety-sensitive work such as flying, driving, operating weapons, and making command and control decisions. The red area on the chart represents performance effectiveness after 2 days and a night of sleep deprivation. Workers in this area are highly likely to fall asleep on the job.

The thin red line is referenced to the right-hand vertical axis, scaled from 0001h at the bottom, through noon to midnight at the top. This plot shows the process of re-alignment of the body's circadian rhythm phase with the day-night cycle in the new time zone.

Five geographic locations were used as examples for origin, destination and deployment transition points in this TM:

- Origin for eastward deployment and destination for westward deployment: Vancouver, British Columbia, Canada; located at 48 deg 11 min N, 123 deg 10 min W; time zone GMT-8 hours (Z-8h).
- Origin for westward deployment and destination for eastward deployment: Kabul, Afghanistan; located at 34 deg 31 min N, 64 deg 12 min E; time zone Z+4.5h.

---

<sup>6</sup> R&D should be directed toward the use of bright light at night in the cockpit while flying continuously in instrument meteorological conditions.

- Eastward and westward transition point: Gander, Newfoundland, Canada; located at 48 deg 57 min N, 54 deg 34 min W; time zone Z-3.5h.
- Eastward transition point: Frankfurt, Germany; located at 50 deg 2min N, 8 deg 34 min E; time zone Z+1h.
- Westward transition point: Glasgow, Scotland; located at 55 deg 53 min N, 4 deg 15 min W; time zone = Z.

## **EASTWARD DEPLOYMENT OF 4.5 HOURS**

### **DAY WORK IN THE NEW TIME ZONE**

Imagine that a crew has shifted 4.5 hours east in one day (Vancouver to Gander: Z-8h to Z-3.5h, 5+00 enroute, 1700-2300Z) and that the crew's circadian rhythms then "chase" the new local time, phase advancing at about 40 minutes per day, targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, local, daytime, 12-h crew duty period (CDP) of 0700-1900L (1030-2230Z) immediately upon arrival in the destination time zone. The crew sleeps moderately well for 6 hours the first night (0000-0600L, 0330-0930Z) and 8 hours the second night (2200-0600L, 0130-0930Z), then continues with 8 hours of excellent sleep per night (2200-0600L).<sup>7</sup>

*FAST*<sup>TM</sup> predicts that full acclimation to the new time zone will take about 8 days in the new location (Figure 1). The crew will be unable to operate at or above 90% cognitive performance effectiveness throughout the 12-h CDP until Day 6 in the new time zone. This is a situation in which the primary fatigue countermeasure, sleep, is necessary but not sufficient. Additional countermeasures are needed to elevate cognitive performance effectiveness to an acceptable level. These may include the tactical use of caffeine<sup>8</sup> or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

<sup>7</sup> Standard times were used for all predictions. The predictions differ little for daylight savings time.

<sup>8</sup> Limit daily caffeine consumption to 250 mg or less so that it is an effective countermeasure when needed.

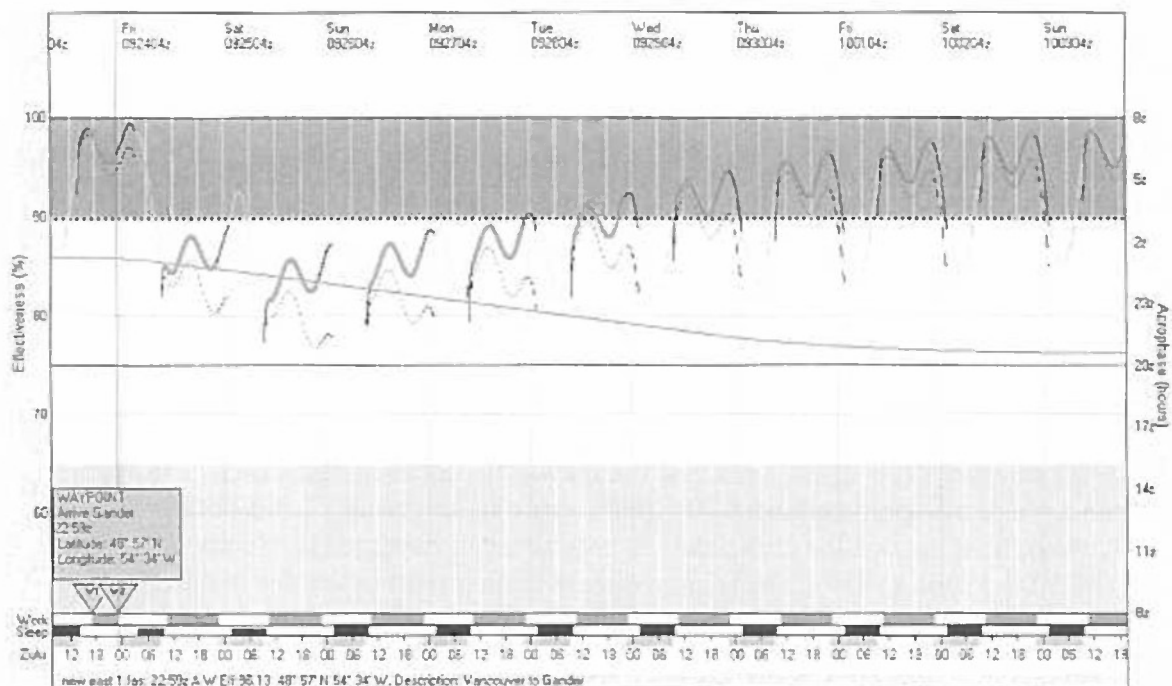


Figure 1. A rapid, eastward, 4.5-hour time zone change on Day 0, followed by day work (red bars) and acclimation to the new time zone across 10 days. The thin red line (in the yellow area), referenced to the right-hand vertical axis, shows the process of re-alignment of the circadian rhythm acrophase with the new time zone.

#### Recommendation for Daytime Missions Following a 4.5-Hour Eastward Deployment

- For the first 4 or 5 days in the new time zone, additional countermeasures other than sleep are needed to elevate cognitive performance effectiveness during daytime missions to an acceptable level. These countermeasures may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### **NIGHT WORK IN THE NEW TIME ZONE**

Conversely, if this same crew must begin 12-h night CDPs (1900-0700L; 2230-1030Z) upon arrival in the new time zone, no mission should be flown on the night of Day 1 and missions should be terminated early for several days to allow the crew's sleep period to adjust (Figure 2). The early termination times would be 0500Z, 0500Z, 0530Z, and 0600Z on Days 2 through 5, respectively (as shown in Figure 2). Subsequently, countermeasures other than sleep should be used to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

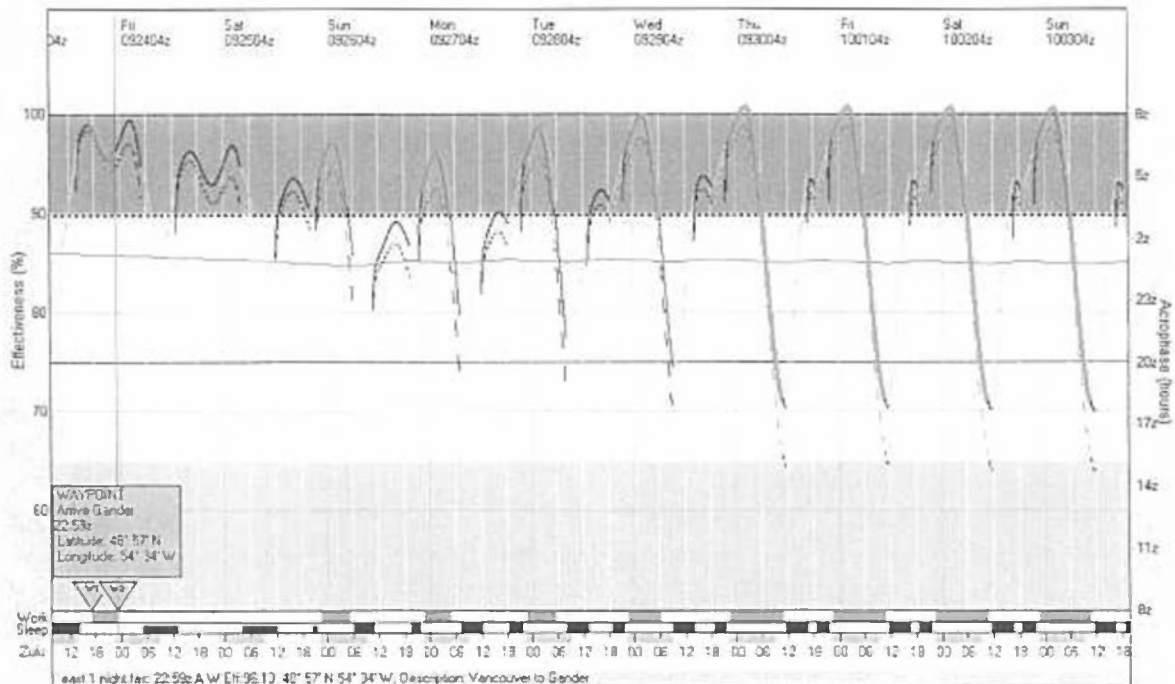


Figure 2. A rapid, eastward, 4.5-hour time zone change on Day 0, followed by night work (red bars) and acclimation to the new time zone across 2 weeks.

#### Recommendations for Nighttime Missions Following a 4.5-Hour Eastward Deployment

- Do not schedule a mission for the night of Day 1 in the new time zone.
- Terminate missions early, at 0500Z, 0500Z, 0530Z, and 0600Z on Days 2 through 5, respectively.
- Subsequently, use other countermeasures in addition to sleep to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

### **EASTWARD DEPLOYMENT OF 9 HOURS**

#### **DAY WORK IN THE NEW TIME ZONE**

Imagine that the same crew shifts 9 time zones east in two days (Vancouver to Gander, as above, then Gander to Frankfurt: Z-8h to Z+1h, 8+00 enroute, 1500-2300Z) and that the crew's circadian rhythms "chase" the new local time, including sleeping earlier each night (a phase advance of the body clock at 40 minutes per day), targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, daytime crew duty period (CDP) that starts at 0700h local on the first day in the destination time zone, with a desired 12-h CDP. The crew sleeps moderately well enroute and the first two nights in the new time zone, then excellently while the sleeping period advances until it stabilizes at 2200h to 0600h local.

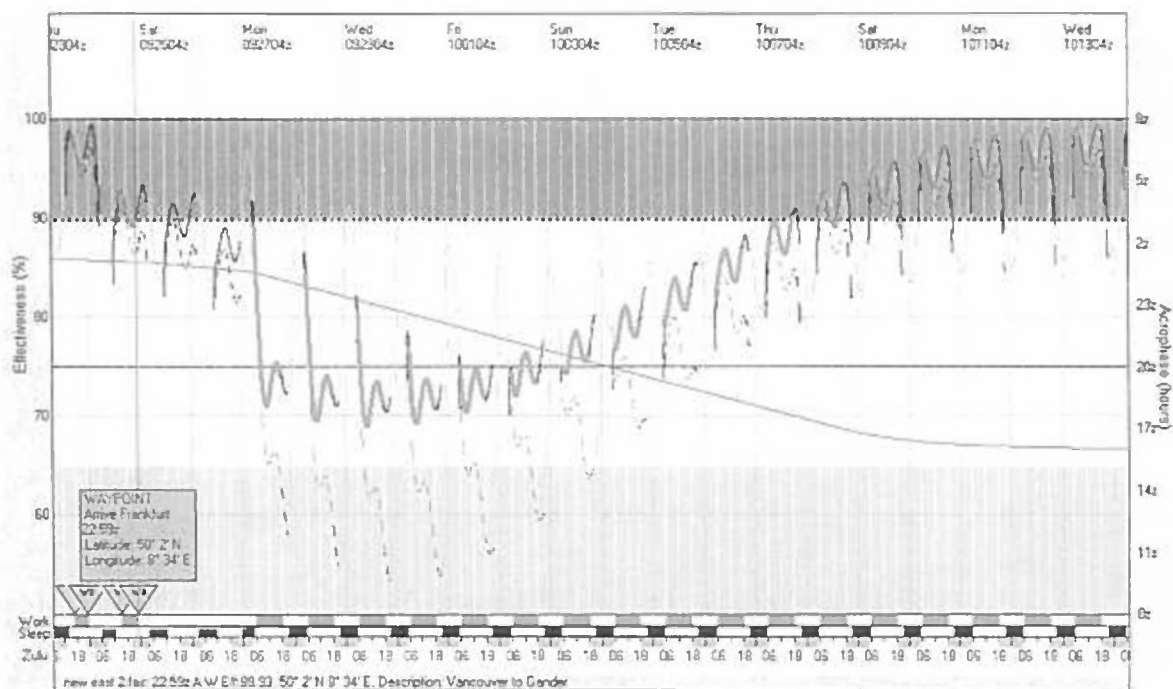


Figure 3. A rapid, eastward, 9-hour time zone change on Days 0 and 1, followed by day work (red bars; 12-h crew duty periods) and acclimation to the new time zone across 3 weeks.

*FAST*<sup>TM</sup> predicts that full acclimation to the new time zone will take about 2 weeks in the new location (Figure 3). As may be seen in Figure 3, portions of all hypothetical 12-h CDPs on the 2 weeks in the new time zone would fall below 90% cognitive performance effectiveness. This, again, is a situation in which the primary fatigue countermeasure, sleep, is necessary but not sufficient. Additional countermeasures are needed to elevate cognitive performance effectiveness to an acceptable level. These may include the tactical use of caffeine<sup>9</sup> or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### Recommendation for Daytime Missions Following a 9-Hour Eastward Deployment

- Do not schedule missions for the first 2 days in the new time zone.
- For the next 10 days in the new time zone, use additional countermeasures to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical use of caffeine<sup>10</sup> or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### **NIGHT WORK IN THE NEW TIME ZONE**

A rapid change of about 9 to 12 hours east or west may shift an individual naturally and quickly from a day worker into a night worker or vice versa. Imagine the crew in the example above arriving in Frankfurt and being assigned to 12-h, night CDPs of 1900-0700L (1800-0600Z). The way to exploit this biological phenomenon for this crew is to not

<sup>9</sup> Limit daily caffeine consumption to 250 mg or less so that it is an effective countermeasure when needed.

<sup>10</sup> Limit daily caffeine consumption to 250 mg or less so that it is an effective countermeasure when needed.

schedule missions for the first three days in the new time zone while the crew's sleep period acclimates partially (Figure 4). Subsequently, the mission should be terminated by 0500Z or additional countermeasures should be used to elevate cognitive performance effectiveness to an acceptable level during the final hour of the CDP. These may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

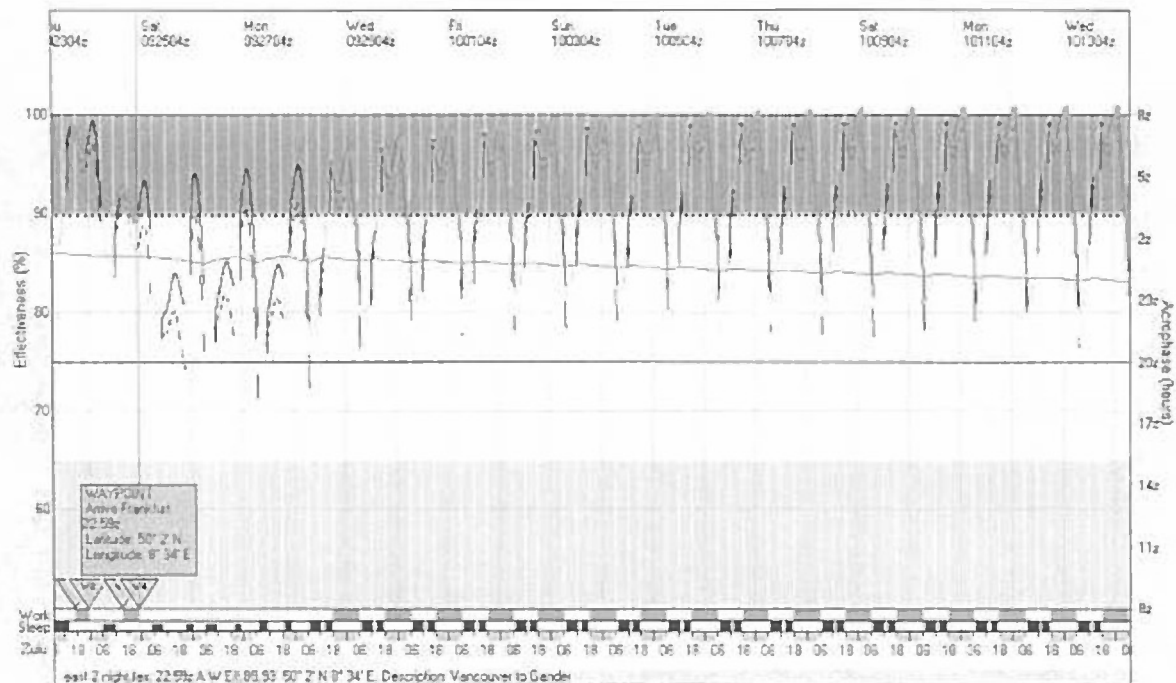


Figure 4. A rapid, eastward, 9-hour time zone change on Days 0 and 1, followed by night work (red bars; 12-h crew duty periods) and acclimation to the new time zone across 3 weeks.

#### Recommendation for Nighttime Missions Following a 9-Hour Eastward Deployment

- Schedule no missions for the first three days in the new time zone
- Terminate the mission on the third day/night by 0500Z, and then continue with the planned CDP
- Subsequently, terminate the mission by 0500Z or use additional countermeasures to elevate cognitive performance effectiveness to an acceptable level during the final hour of the CDP

#### General Recommendation for Scheduling Following a 9-Hour Eastward Deployment

- Schedule night missions, not day missions.

## EASTWARD DEPLOYMENT OF 12.5 HOURS

### DAY WORK IN THE NEW TIME ZONE

Imagine that the same crew shifts 12.5 time zones east in three days (Vancouver to Gander and Gander to Frankfurt, as above, then Frankfurt to Kabul: Z-8h to Z+4.5h, 6+00 enroute, 1300-1900Z) and that the crew's circadian rhythms "chase" the new local time, including sleeping earlier each night (a phase advance of the body clock at 40 minutes per day), targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, daytime crew duty period (CDP) that starts at 0700h local in the destination time zone, with a desired 12-h CDP. The crew sleeps moderately well enroute and the first three nights in the new time zone, then excellently while the sleeping period advances until it stabilizes at 2200h to 0600h local.

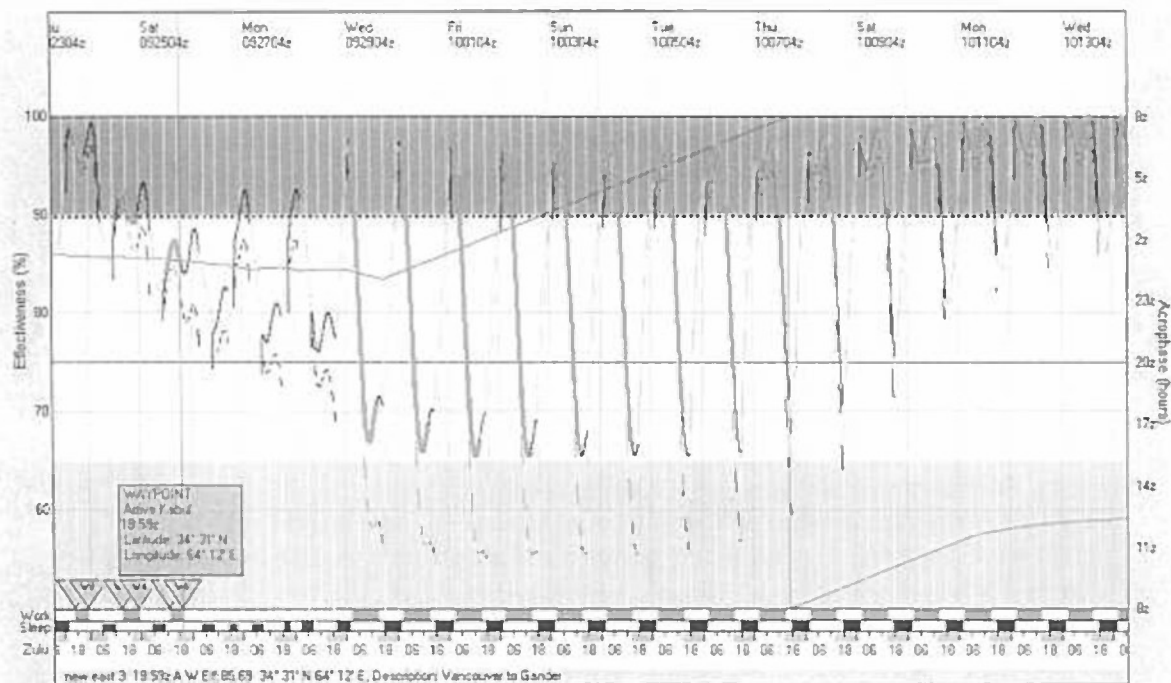


Figure 5. A rapid, eastward, 12.5-hour time zone change on Days 0 through 2, followed by day work (red bars; 12-h crew duty periods) and acclimation to the new time zone across 3 weeks.

*FAST*<sup>TM</sup> predicts, first, that there will be high risk of fatigue-induced errors on the third deployment leg. Subsequently, it predicts that full acclimation to the new time zone will take about 2 weeks in the new location (Figure 5). Sleep will likely be fragmented during the first several days in the new time zone, and missions should not be scheduled then. As may be seen in Figure 3, portions of all hypothetical 12-h CDPs on the subsequent 10 days in the new time zone would fall below 90% cognitive performance effectiveness. This, again, is a situation in which the primary fatigue countermeasure, sleep, is necessary but not sufficient. Additional countermeasures are needed to elevate cognitive performance effectiveness to an acceptable level. These may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### Recommendation for Daytime Missions Following a 12.5-Hour Eastward Deployment

- Do not schedule missions for the first 2 days in the new time zone.
- For the next 10 days in the new time zone, use additional countermeasures to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### **NIGHT WORK IN THE NEW TIME ZONE**

Imagine the crew in the example above arriving in Kabul and being assigned to 12-h, night CDPs of 1900-0700L (1430-0230Z). *FAST*<sup>TM</sup> predicts, first, that there will be high risk of fatigue-induced errors on the third deployment leg. Subsequently, the way to exploit the crew's natural circadian rhythm is to not schedule missions for the first four days in the new time zone and then continue with the planned CDP (as shown in Figure 6). There will be some risk of fatigue-induced errors during the slump at 2000Z on Day 5. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

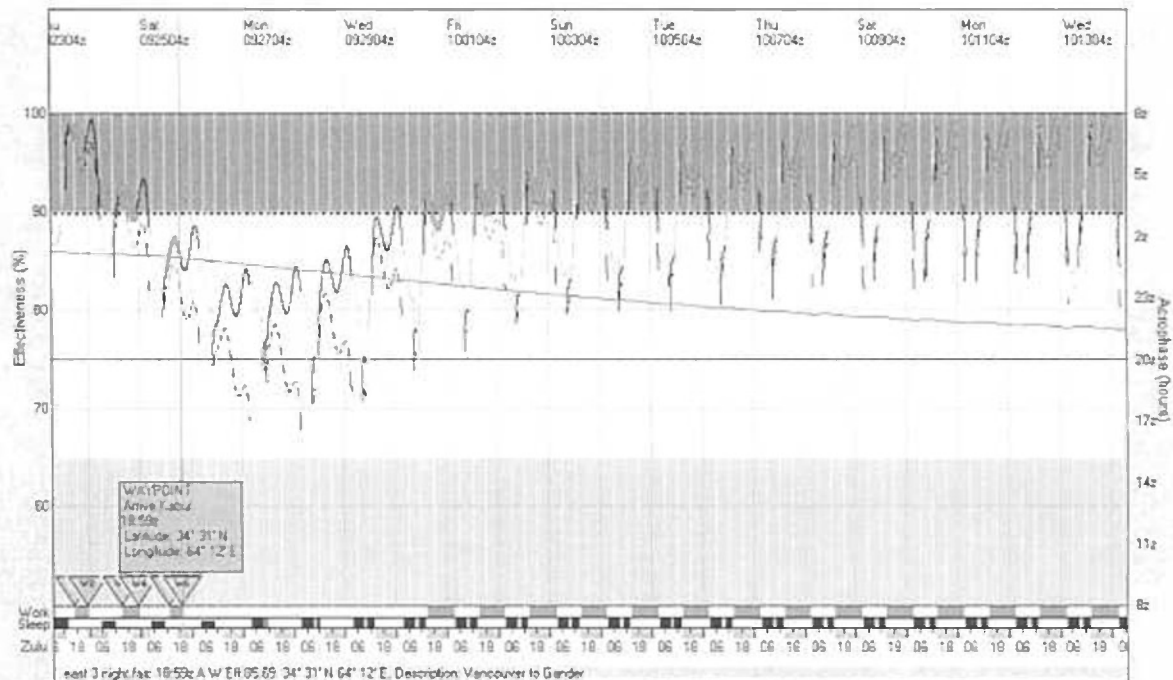


Figure 6. A rapid, eastward, 12.5-hour time zone change on Days 0 through 2, followed by night work (red bars; 12-h crew duty periods) and acclimation to the new time zone across 3 weeks.

#### Recommendation for Nighttime Missions Following a 12.5-Hour Eastward Deployment

- Schedule no missions for the first four days in the new time zone and then continue with the planned CDP.
- Exercise extra caution around 2000Z on Day 5 in the new time zone.

#### General Recommendation for Scheduling Following a 12.5-Hour Eastward Deployment

- Schedule night missions, not day missions.

## WESTWARD DEPLOYMENT OF 4.5 HOURS

### DAY WORK IN THE NEW TIME ZONE

Imagine that a crew has shifted 4.5 hours west in one day (Kabul to Prestwick: Z-4.5h to Z+/-0h, 6+00 enroute, 0430-1030Z) and that the crew's circadian rhythms then "chase" the new local time, phase delaying at about 1 hour per day, targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, local, daytime, 12-h crew duty period (CDP) of 0700-1900L (1700-1900Z) immediately upon arrival in the destination time zone.

*FAST*<sup>TM</sup> predicts that full acclimation to the new time zone will take about 6 days in the new location (Figure 7). However, except for the last hour of the new CDP, predicted cognitive performance effectiveness remains at or above 90% throughout the CDP. All of the CDP may be kept above 90% effectiveness by terminating the mission on Day 1 by 1800Z and on Day 2 by 1830Z, as shown in Figure 7.

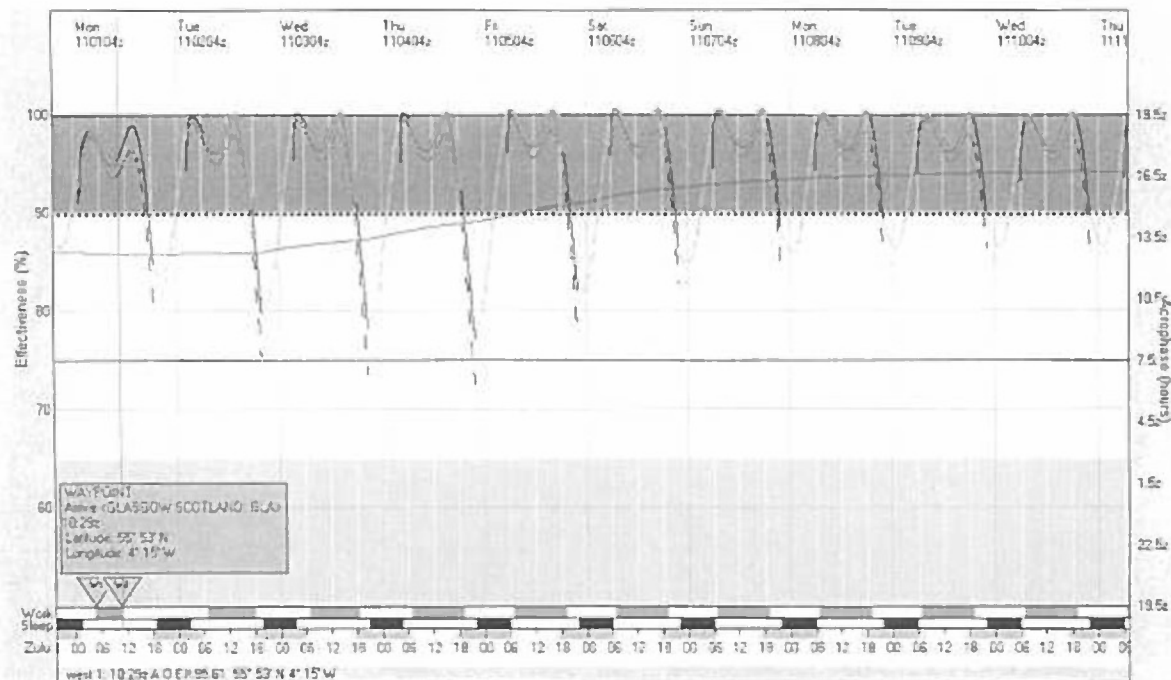


Figure 7. A rapid, westward, 4.5-hour, time zone change on Day 0, followed by day work (red bars) and acclimation to the new time zone across 10 days.

### Recommendation for Daytime Missions Following a 4.5-Hour Westward Deployment

- Terminate missions by 1800Z and 1830Z on Days 1 and 2, respectively.

### NIGHT WORK IN THE NEW TIME ZONE

Conversely, if this same crew must begin 12-h night CDPs (1900-0700L; 1900-0700Z) upon arrival in the new time zone, *FAST*<sup>TM</sup> predicts that portions of all 12-h CDPs would fall below 90% cognitive performance effectiveness. This, again, is a situation in which the primary fatigue countermeasure, sleep, is necessary but not sufficient. Additional countermeasures are needed to elevate cognitive performance effectiveness to an acceptable level. These may include the tactical use of caffeine or medically-prescribed modafinil.

(Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

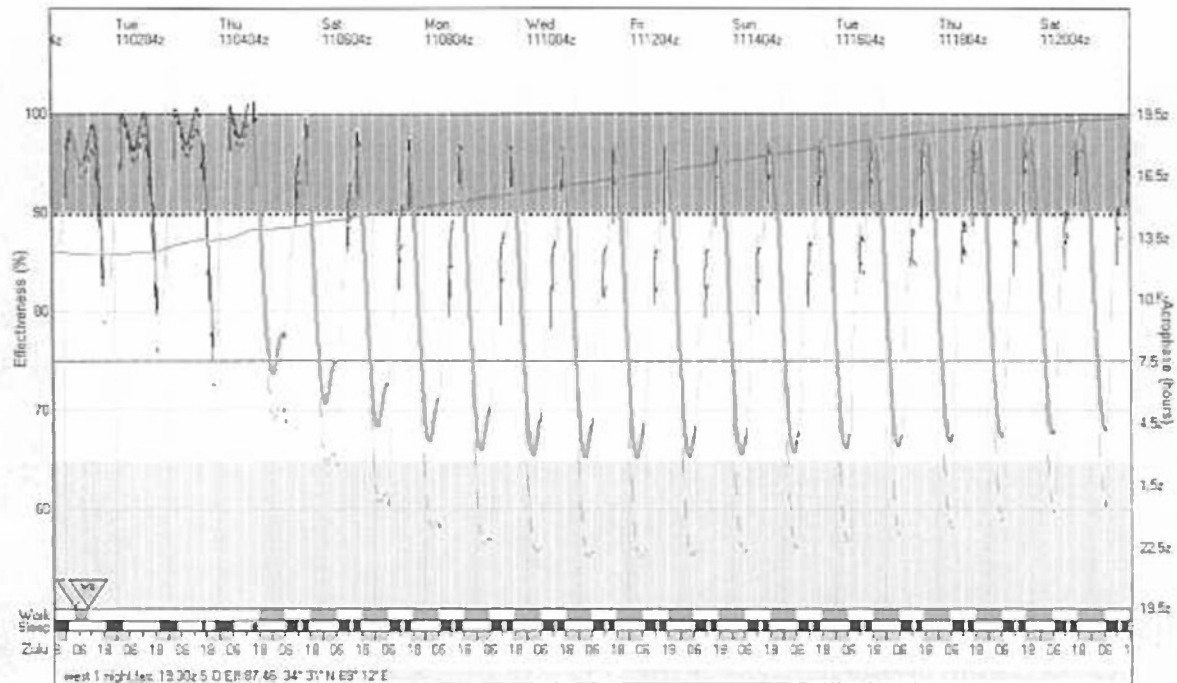


Figure 8. A rapid, westward, 4.5-hour, time zone change on Day 0, followed by night work (red bars) and acclimation to the new time zone across 3 weeks.

#### Recommendation for Nighttime Missions Following a 4.5-Hour Westward Deployment

- Do not schedule missions for the first 3 days in the new time zone while the crew sleep period acclimates partially to the new time zone.
- Subsequently, use additional countermeasures to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

#### General Recommendation for Scheduling Following a 4.5-Hour Westward Deployment

- Schedule day missions, not night missions.

### **WESTWARD DEPLOYMENT OF 9 HOURS**

#### **DAY WORK IN THE NEW TIME ZONE**

Imagine that a crew has shifted 9 hours west in two days (Kabul to Prestwick, as above, then Prestwick to Gander: Z+/-0h to Z-3.5h, 8+00 enroute, 0530-1330Z) and that the crew's circadian rhythms then "chase" the new local time, phase delaying at about 1 hour per day, targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, local, daytime, 12-h crew duty period (CDP) of 0700-1900L (1030-2230Z) immediately upon arrival in the destination time zone.

*FAST*<sup>TM</sup> predicts that full acclimation to the new time zone will take about 6 days in the new location (Figure 9). However, except for the last hour of the first CDP, predicted cognitive performance effectiveness will remain at or above 90% for all CDPs in the new time zone. The first mission should be terminated by 1800Z, as shown in Figure 9.

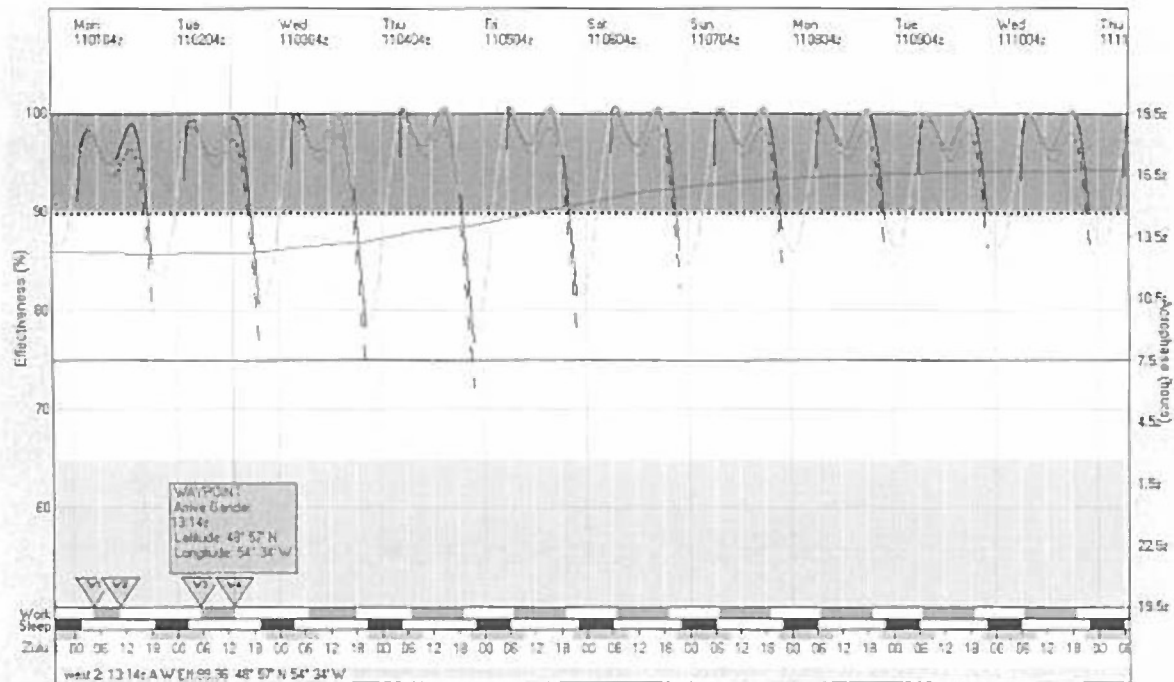


Figure 9. A rapid, westward, 9-hour, time zone change on Days 0 and 1, followed by day work (red bars) and acclimation to the new time zone across 10 days.

#### Recommendation for Daytime Missions Following a 9-Hour Westward Deployment

- Terminate first mission by 1800Z.

#### **NIGHT WORK IN THE NEW TIME ZONE**

Conversely, if this same crew must begin 12-h night CDPs (1900-0700L; 2230-1030Z) upon arrival in the new time zone, *FAST*<sup>TM</sup> predicts that all 12-h CDPs would fall below 90% cognitive performance effectiveness. This, again, is a situation in which the primary fatigue countermeasure, sleep, is necessary but not sufficient. Additional countermeasures are needed to elevate cognitive performance effectiveness to an acceptable level. These may include the tactical use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

#### Recommendation for Nighttime Missions Following a 9-Hour Westward Deployment

- Do not schedule missions for the first 3 days in the new time zone while the crew sleep period acclimates partially to the new time zone.
- Subsequently, use additional countermeasures to elevate cognitive performance effectiveness to an acceptable level. These countermeasures may include the tactical

use of caffeine or medically-prescribed modafinil (Provigil®) or dextroamphetamine (Dexedrine®), in accord with approved policies.

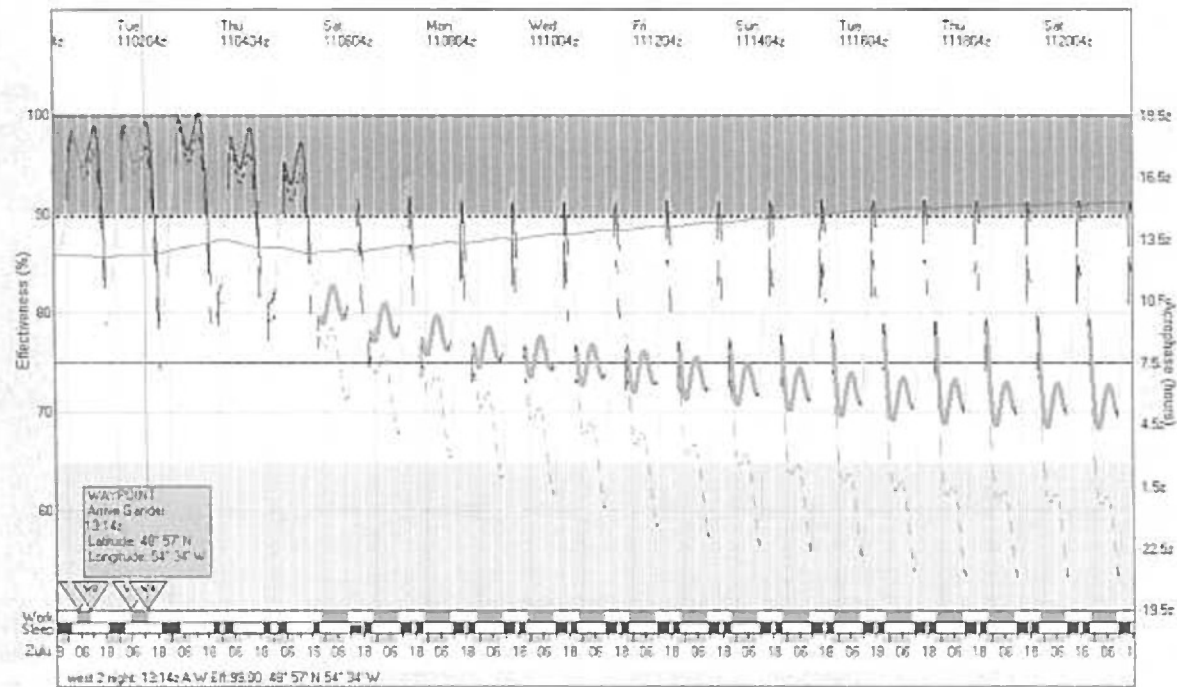


Figure 10. A rapid, westward, 9-hour, time zone change on Days 0 and 1, followed by night work (red bars) and acclimation to the new time zone across 10 days.

#### General Recommendation for Scheduling Following a 9-Hour Westward Deployment

- Schedule day missions, not night missions.

### **WESTWARD DEPLOYMENT OF 12.5 HOURS**

#### **DAY WORK IN THE NEW TIME ZONE**

Imagine that a crew has shifted 12.5 hours west in three days (Kabul to Prestwick and Prestwick to Gander, as above, then Gander to Vancouver: Z-3.5h to Z-8h, 6+00 enroute, 0630-1230Z) and that the crew's circadian rhythms then "chase" the new local time, phase delaying at about 1 hour per day, targeting a 2200-0600L sleep period. Also, imagine that the crew takes up a new, local, daytime, 12-h crew duty period (CDP) of 0700-1900L (1500-0300Z) immediately upon arrival in the destination time zone.

*FAST*<sup>TM</sup> predicts that full acclimation to the new time zone will take about 10 days in the new location (Figure 11). However, predicted cognitive performance effectiveness will remain at or above 90% for all CDPs in the new time zone.

#### Recommendation for Daytime Missions Following a 12.5-Hour Westward Deployment

- Initiate daytime CDPs immediately.

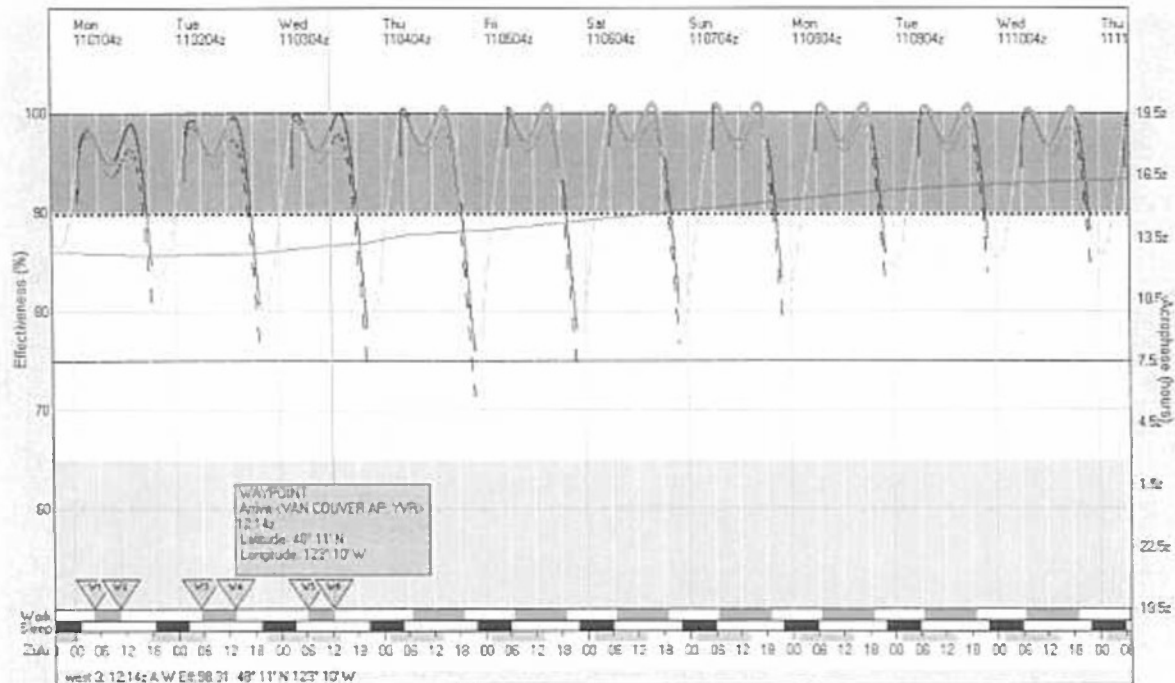


Figure 11. A rapid, westward, 12.5-hour, time zone change on Days 0 through 2, followed by day work (red bars) and acclimation to the new time zone across 10 days.

## NIGHT WORK IN THE NEW TIME ZONE

As mentioned above, a rapid change of about 9 to 12 hours east or west may shift an individual naturally and quickly from a day worker into a night worker or vice versa. If this same crew were to acclimatize for two days and then begin 12-h night CDPs (1900-0700L; 0300-1500Z) upon arrival in the new time zone, *FAST*<sup>TM</sup> predicts that the majority of CDPs would fall above 90% cognitive performance effectiveness (Figure 12). There would be risks of fatigue-induced errors during the 0900-1100Z period during the first week of missions. The difference between this prediction and that for night CDPs after a 9-h westward deployment is that the circadian rhythm phase-advances in this situation, back toward the day-work schedule on the opposite side of the earth, instead of phase-delaying, as in the 9-h deployment with night CDPs. Also, see the night work Technical Memorandum cited above for a more complete discussion of night flying.

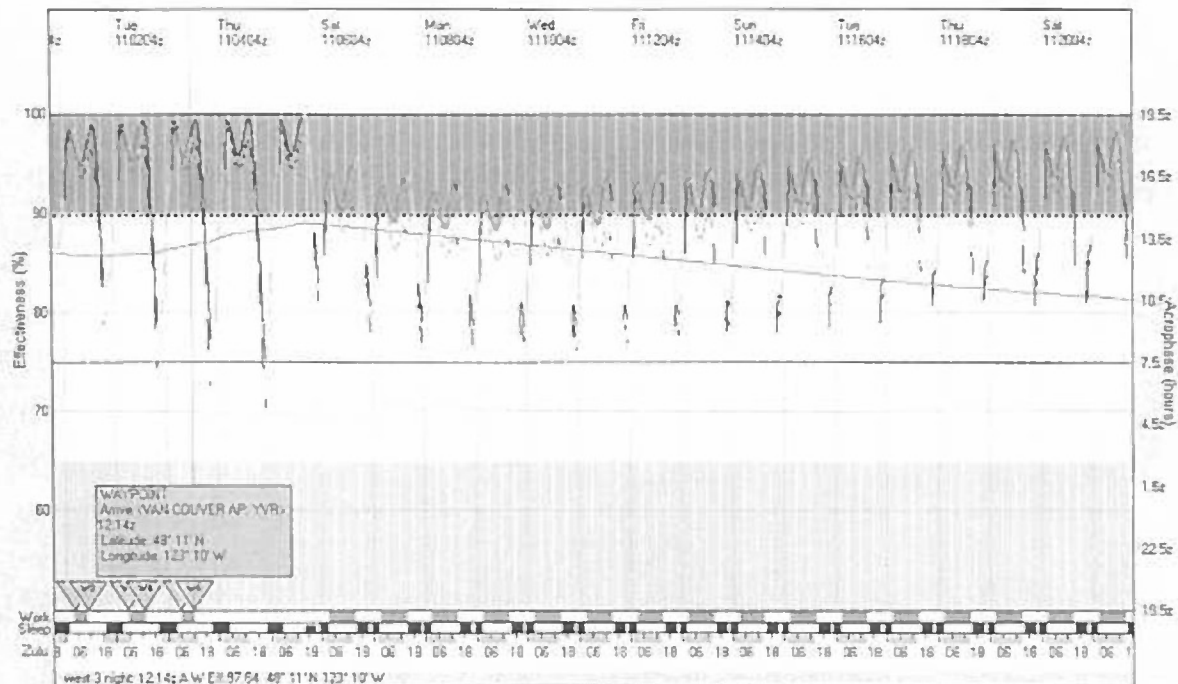


Figure 12. A rapid, westward, 12.5-hour, time zone change on Days 0 through 2, followed by night work (red bars) and acclimation to the new time zone across 3 weeks.

#### Recommendation for Nighttime Missions Following a 12.5-Hour Westward Deployment

- Allow two days for the crew's sleep period to acclimate partially, then initiate daytime CDPs.

### USING BRIGHT LIGHT TO HELP ACCLIMATE

Bright light exposures in the new time zone before and after the expected sleep period may accelerate phase delays and phase advances, respectively, of one's circadian rhythms. However, in the absence of real-time, accurate knowledge of the expected sleep period, there is a substantial risk that inappropriately-timed bright light exposures will aggravate shift lag.

Given knowledge of this risk, a crew may wish to refer to the calculator at the web site of Outside In, Ltd.<sup>11</sup> It appears that this calculator may be used safely, with three caveats.

- First, emphasize to the crews that the times cited for light exposure are local at the new location.
- Second, emphasize that going beyond the prescription (i.e., using it for more days than prescribed on the site) is not advisable. The reason for this is that, after a couple of days of light therapy in the new time zone, you no longer know exactly the timing of your expected sleep period.
- Finally<sup>12</sup>, emphasize to the crews that each person's response to the light exposure may vary. Thus, if it isn't working for you but it is for your friend, go with what your

<sup>11</sup> <http://www.bodyclock.com/index.htm>.

body is telling you, not what is happening with your friend. Your circadian rhythm may be slightly different from your friend's and therefore respond differently

“Another way to look at the use of bright light to move the melatonin peak around is to imagine a long, skinny balloon that is inflated just in the middle and still skinny at both ends. The inflated bubble represents the melatonin peak that occurs between midnight and dawn. If you squeeze the right-hand part of the bubble, it will shift left. That’s like morning light pushing the peak earlier. If you squeeze the left-hand part of the bubble, it will shift right. That’s like evening light pushing the melatonin peak later.”<sup>13</sup> What's not said clearly here is that the middle bubble is your expected sleep period, based upon your home sleep period and the sleep period's subsequent phase changes with respect to the new, local day-night cycle.

---

<sup>12</sup> Dr. J. Lynn Caldwell, personal communication.

<sup>13</sup> Miller JC, *Controlling Pilot Error: Fatigue*, McGraw-Hill, 2001.

